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High Gain 2.45 GHz 2x2 Patch Array Stacked Antenna

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***Abstract*—This paper presents 2x2 patch array antenna for 2.45 GHz industrial, scientific and medical (ISM) band application. In this design, four array radiating elements interconnected with a transmission line and excited by 50Ω subminiature (SMA). The proposed antenna structure is combined with a reflector in order to investigate the effect of air gap between radiating element and reflector in terms of reflection coefficient (S_{11}) bandwidth and realized gain. The analysis on the effect of air gap has significantly achieved maximum reflection coefficient and realized gain of -16 dB and 19.29 dBi respectively at 2.45 GHz.**

Keywords—patch array antenna, high gain antenna, 2.45 GHz stacked antenna.

I. INTRODUCTION

Microstrip patch antennas provide an attractive solution to compact, conformal, and low-cost designs of various emerging wireless application systems. Microstrip patch antenna also requires ease of fabrication and installation. However, it is a well-known fact that the gain of a patch antenna is usually low [1, 2]. Therefore, this research proposed a simple microstrip antenna design that achieved a peak gain of 19.29 dBi.

The proposed antenna has been developed by applying 2x2 arrays square on radiating element. At each square of array element, two chamfer edges with width 7mm are applied to improve the polarization capability. The circular polarized antennas are widely used in wireless communication system due to optimized global efficiency and decrease the polarization losses [3-5].

The ground plane and reflector is important elements of a microstrip patch antenna, since it affects many of the antenna's characteristics [6]. Thus, it is necessary for an antenna designer to understand the effects of the ground plane to the antenna characteristics. In [7], partial ground plane is able to realize the omni-directional radiation pattern. A lot of bandwidth enhancement techniques have been suggested and designed in [8, 9]. Bandwidth of antenna can be increased by designing the antenna with an air gap between radiating element and reflector.

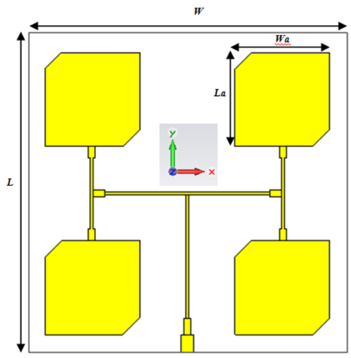
The proposed antenna is designed and successfully achieved outstanding performance within operating frequency of 2.45 GHz. Moreover, such antenna manage to achieve minimum reflection coefficient of S_{11} < -10dB which is suitable for industrial, scientific and medical (ISM) band application that has been regulated by the Malaysian Communication and Multimedia Commission (MCMC) [1, 7].

The paper is organized as follows: the design and structure of DPTA are described in Section II. The simulated analysis effect of air gap on proposed antenna is then presented in the following section. Finally, a conclusion is drawn in Section IV.

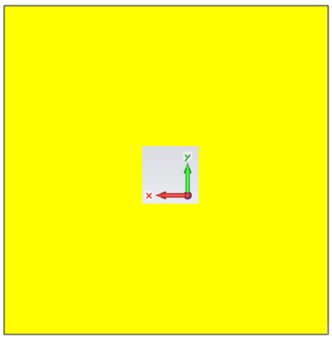
II. ANTENNA DESIGN

The proposed antenna is printed on a Taconic (TLY-5) substrate with dielectric constant, ε_r = 2.2, thickness of t = 1.5478+/-0.02, tangent loss of tanδ = 0.0009 and copper thickness of 35μm. TLY-5 dielectric is used with due to the low εr that help to improve the antenna efficiency for both with and without air gap configuration.

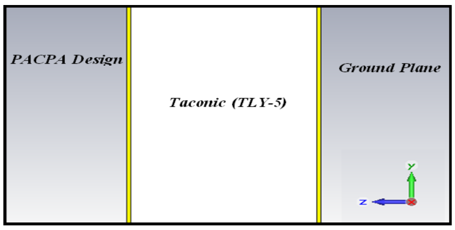
The 180 mm² reflector of the proposed antenna is also deployed Taconic board. The reflector located at the back of proposed antenna with various distance of air gap.



(a)



(b)



(c)

Fig. 1. Simulated structure of the proposed antenna. (a) Front view of radiating element. (b) Rear view of refector. (c) Layout view of TLY-5.

The structure of the proposed antenna is depicted in Figure 1, with the implementation of array technique where four radiating elements are interconnected to each and other through transmission line. Figure 1(a) demonstrated front view of radiating surface with dimension 140mm². Figure 1(b) depicts the reflector of antenna from rear view and layout of Taconic board (TLY-5) is shown in Figure 1(c). Geometrical dimension of the proposed antenna is tabulated in Table I.

TABLE I. Geometrical Parameter of proposed antenna.

Parameter	Dimension (mm)
W	140
L	140
Wa	40
La	40
Wr	180
Lr	180

III. RESULT AND DISCUSSION

To investigate effect of air gap of the proposed antenna simulated to analyze the reflection coefficient (S_{11}), gain, and surface current distribution and the result of the antenna are discussed in the following sub-sections.

A. Reflection Coefficient (S_{11})

Reflection coefficient (S_{11}) is the ratio of the amplitude of a wave reflected from a surface to the amplitude of the incident wave. In wireless communication, the acceptable for reflection coefficient (S_{11}) is -6 dB which represent about 30 % reflected and 70% radiated.

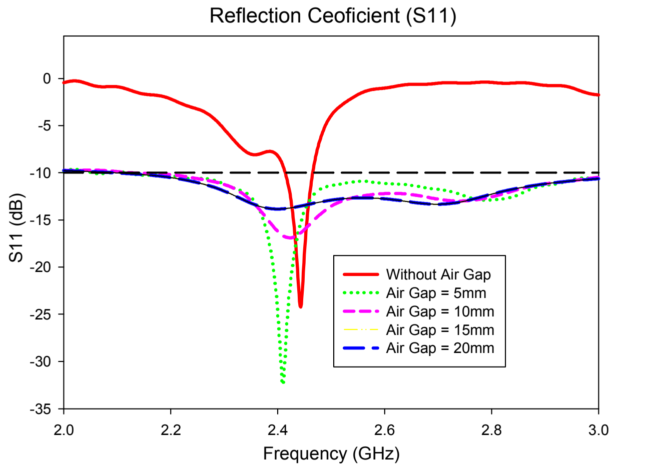
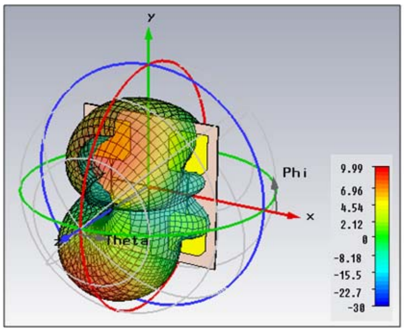


Fig. 2. Simulated Reflection Coefficient (S_{11}) Result at 2.45 GHz in Various Air Gap Between Radiating Element and Reflector.

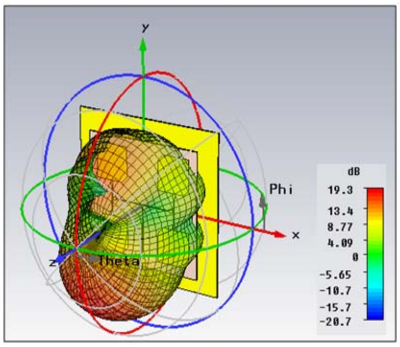
Figure 2 clearly demonstrates the simulated reflection coefficient (S_{11}) at 2.45 GHz in various air gap between radiating Element and reflector. Maximum S_{11} is 16 dB at 2.45 GHz. Acceptable S_{11} result of < -10dB is achieved for both with or without reflector. However with the reflector, the bandwidth of proposed antenna is increased up to 46.15%.

B. Radiation Pattern

In Figure 3, the simulated 3-D radiation pattern of the proposed antenna at operating frequency of 2.45 GHz is shown. The maximum gain of the proposed antenna without air gap and reflector is 9.98 dBi. Meanwhile, Figure 3(b) shows maximum gain of the proposed antenna with air gap and reflector is 19.29 dBi.



(a)



(b)

Fig. 3. 3-D simulation radiation pattern of the PACPA (a) Without air gap and reflector (b) With air gap and reflector.

Figure 4 demonstrates Cartesian realized gain plot of proposed antenna. It is clearly shows that applied reflector and suitable air gap between radiating element and reflector be capable of enhance realized gain of propose antenna. Effect of air gap between radiating element and reflector in term of gain clearly obtained as summarized in Table II.

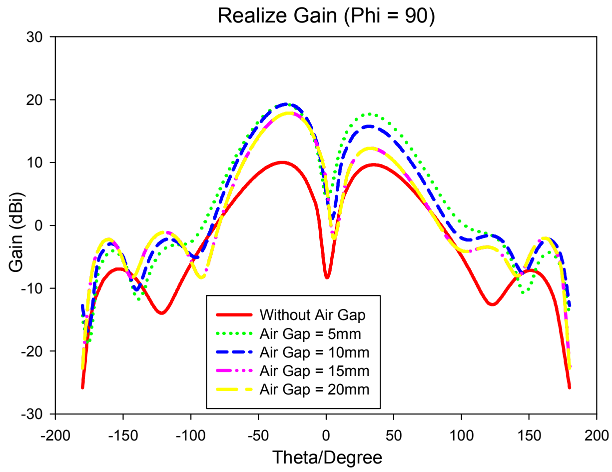
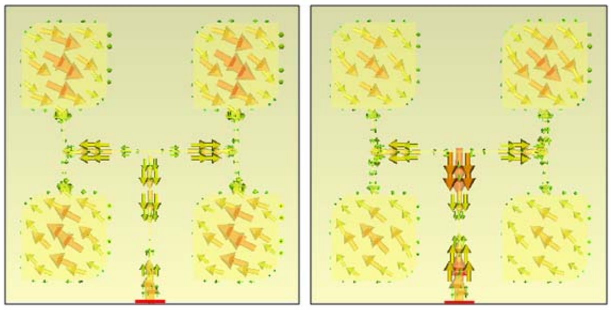
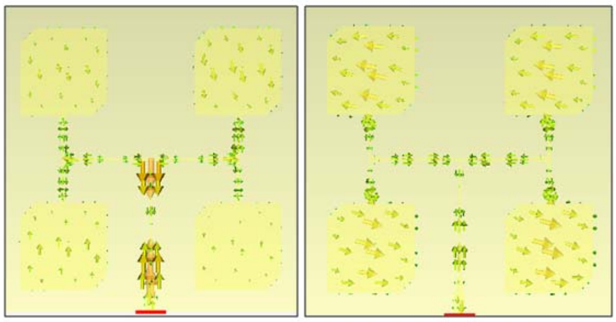


Fig. 4. Simulated Realize Gain at 2.45 GHz in Various Aip Gap Between Radiating Element and Reflector.

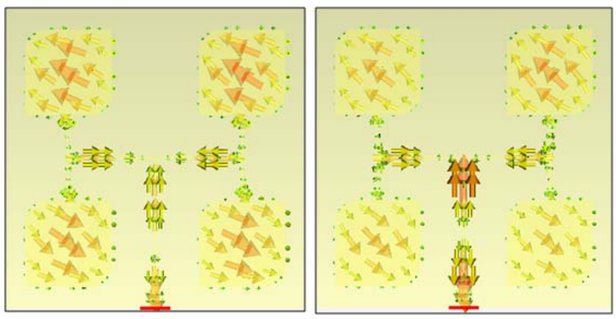
C. Surface Current



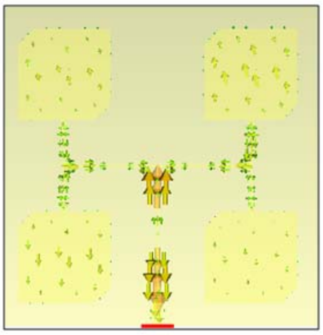
(a) (b)



(c) (d)



(e) (f)



(g)

Fig. 5. Surface Current Distribution at 2.45 GHz in Various Degrees. (a) 0□ / 360□ (b) 45□ (c) 90□ (d) 134□ (e) 180□ (f) 225 □ (g) 270□

The H-field surface current distribution is observed at 2.45 GHz over the certain degree as shown in Figure 5. The current flows from SMA port through transmission line to array radiating element. Figure 5 (a), (b), (c), (d), (e), (f), and (g) clearly demonstrated that proposed antenna be able to perform as elliptical polarization.

TABLE II. Simulated antenna performance for different Air Gap configurations

Parameter Air Gap	Without	5mm	10mm	15mm	20mm
S_{11} at 2.45 GHz (dB)	-18.65	-14.04	-16.00	-13.44	-13.44
Bandwidth (%)	2.05	32.00	35.29	43.13	46.15
Realize Gain (dBi)	9.98	19.26	19.29	17.83	17.83

IV. CONCLUSION

A 2x2 patch array high gain antenna is proposed for 2.45 GHz ISM band application. This research has successfully investigated the effect of air gap between radiating element and reflector. The antenna excited by 50Ω subminiature (SMA) probe to feed current flow to radiating element through transmission line. The proposed antenna deployed reflector in order to enhance the realized gain and investigate effect of air gap to microstrip antenna. Assisted with air gap configuration, the antenna is able to increase bandwidth percentage of up to 46.15% and realized gain of 19.29 dBi under acceptance value of S_{11}. Based on surface current distribution, the proposed antenna is able to function in elliptical polarization in order to reduce the polarization losses. With all capabilities demonstrated and discussed, the proposed antenna has sufficiently competent for ISM band application.

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